Ph.D. Pre-registration Synopsis

Malwad Dnyaneshwar S.

S.G.G.S I E &T Nanded

Pre-registration synopsis

on

Performance Evaluation and Integration of Solar Thermal Systems

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Malwad Dnyaneshwar Shivaji

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Dr. V. B. Tungikar

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SAWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY

NANDED - 431606, Maharashtra State, India.

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1. Introduction

Solar energy is never ending energy obtained from the sun in the form of solar radiation. When these solar radiations falls on absorbing surface, then they gets changed into the heat, this heat can be successfully utilized by collecting through photovoltaic and solar thermal collectors. Photovoltaic systems generate electricity from sunlight and solar thermal system supply heat to working fluid. Solar Collector Technology has good potential for various applications, including power generation and process heating applications. Industrial sector in India consumes about 50% of country's commercial energy. The total energy used by industry, a major portion, approximately 45–65%, is used for direct thermal applications in the preparation and treatment of goods, as industrial process heat (IPH). The thermal energy level of IPH, in general is below the temperature of 250^0 C [9]. Solar thermal collectors are classified by United States energy information administrators as low, medium and high temperature collectors. High temperature collectors are used for fulfilling heat requirements in industries and power generation. The commonly used solar thermal energy technologies are compound parabolic concentrator (CPC), Evacuated tube heat pipe, and scheffler dish.

Compound parabolic concentrator (CPC) is a non-imaging type of concentrator. CPC designed in such a way that parabola curve reflects all incident sunlight onto a focal point, and thus the concentration of solar energy can be maximised. It is a versatile solar collector due to the amount of applications and geometries that can be used. CPC collectors are better suited for temperatures lower than 130°C.

Scheffler dish is a type of parabolic dish with fixed focus. It is based on the same principle as the CPC, however the dish is parabolic in two dimensions, and the incident sunlight is concentrated toward a single focal point results in higher concentration ratio. It is made up of a number of flat shaped reflective films which are mounted on structural frame. Scheffler reflector performs change in inclination angle while staying directed to sun. It is used where temperature requirement is below 200^0 C. CPC and scheffler dish collectors are excellent collector for thermal energy supply of agricultural and industrial processes for medium temperature applications.

2. Literature Review

L. Salgado Conrado (2017) presented the review on thermal mathematical model, simulation and numerical method for parabolic tough collector (PTC). Thermal models for a PTC collector are developed by considering Heat transfer model, Non-uniform thermal model, One-dimensional and three dimensional thermal model, Statistical model, Energy and exergy model, Dynamic model. All these models have some effectiveness and difficulties. the literature have experimental set-ups for performance of a PTC collector. This study also shows cost management in Parabolic Trough Solar Concentrators is an important tool.

Soteris A. Kalogirou (2016) has given the review on exergy analysis of solar thermal system based on literature published in 2013 &2014. Several types of solar thermal collectors have been analyzed by using exergy efficiency as an indicator. Energy content of solar radiation converted into thermal energy which can be utilized for Drying, Heating, cooling, Desalination, Hydrogen production, Electricity generation and various applications and processes.

Atul S. Jadhav and Ajitkumar S. Gudekar (2013) designed cost effective compound parabolic concentrator (CPC) for various industrial, agricultural and residential applications. Experiments were conducted and results of the experiment were recorded by considering the uncertainties. Results show the average efficiency is 25.7% and the average steam generation rate is 27 kg/h. when the receiver pipe was not surrounded by the glass tubes. When the pipe is surrounded by two glass tubes, the performance was found to be more stable and the average values of efficiency and steam flow rates were 34.2% and 34.5 kg/h, respectively. This study also shows the CPC design is easy to fabricate with low production cost.

Santos-González and M. Sandoval-Reyesa (2014), designed compound parabolic concentrator (CPC) using a one-dimensional model. Experiments were carried out at different mass flow rate and inlet temperature. Experimental result shows the maximum useful energy gain 1.47 kW and highest pressure drop obtained 1.2 kPa at mass flow rate of 12 kg/min. Experimental result shows this technology could be able to supply stable temperatures for industrial processes. They also suggested correction of manufacturing errors in order to improve CPC performance

D.K.Patel and P. K.Brahmbhatt (2015) developed a model for analysis and performance evaluation of compound parabolic concentrator (CPC) by using air as working fluid.

Experimental study and numerical simulation was carried out to study the effect of wind velocity, collector length and mass flow rate on thermal performance of CPC. Results show the improvement in the efficiency of collector with increasing the solar intensity at mass flow rate of 0.012 and 0.016 kg/s due to enhanced heat transfer to the air flow.

Wisut Chamsa-ard Sukruedee Sukchai (2014) tested solar collector by measuring the critical parameters and variable parameters. Result shows that the thermal efficiency, heat loss coefficient a_1 and heat loss coefficient a_2 of the CPC are equal to 78%, 3.55 and 0.0600 W/m2-oC respectively. It was also found that the monthly average energy of the CPC produced throughout the year is equal to 286.16 kWh.

Hamza Hijazi, Ossama Mokhiamar (2016), designed low cost parabolic solar dish concentrator. To compromise between cost and efficiency, stainless steel sheets are used as the reflective surface. The presented results reveal a robust design of the dish concentrator that can deal with various applied forces to provide the minimum possible cost.

José Ruelas, Nicolás Velázquez, Jesús Cerezo (2013), developed a Scheffler-type solar, concentrator by using mathematical model that includes geometric, optical and thermal aspects. Improvement in efficiency by 7% observed as compared with parabolic dish concentrator.

M. Imtiaz Hussain (2017) compared the optical and thermal performance of conical solar collector (CSC) using numerical and experimental finding. Series of experiments were conducted using identical reflector areas for stainless steel reflector (SSR) and aluminum mirror reflector (AMR) for different view angles under similar operating conditions. Maximum thermal efficiency was achieved using AMR with a view angle of 45. These findings were notably higher than those reported with SSR system. This concludes AMR is better reflector as compared with SSR.

Hardik Naika, Prashant Baredar, Anil Kumar (2017), described the need of medium temperature solar technology, potential market and obstacles. Domestic, agricultural, industrial and processes applications of CPC and Scheffler dish solar collector are explained through case studies.

Literature on the CPC and scheffler dish system is scattered. Literature study shows there is not exact method for selecting the parameters for evaluating the performance of compound parabolic concentrators (CPC) and scheffler solar collector. Literature study also shows the

integration of the different types of solar thermal collectors is possible to improve thermal performance of the system and achieve the high temperature for various applications.

3. Problem Definition

There is not exact method for measuring the performance of the concentrated solar heating. Low cost and higher temperature delivering collector technologies are not available to meet higher temperature requirements of agricultural processing equipment and process industries.

4. Objectives

Objectives of this research are:

1. To evaluate performance of compound parabolic concentrator (CPC).
2. To evaluate performance of scheffler dish concentrator.
3. To integrate Compound parabolic concentrator (CPC) and scheffler dish.
4. To develop mathematical model and validate by experimentation.
5. To use integrated system for enhancing productivity of agricultural processing equipment. (Blancher, Dryer etc.)

5. Methodology

In this research performance of CPC and scheffler dish solar thermal collectors can be characterized using critical and variable parameters. Performance of the CPC and scheffler dish can be evaluated by considering the effect of inlet temperature, ambient temperature, wind velocity, mass flow rate, pressure, direct normal irradiance, absorber (concentrator) size and shape, mirror reflectance and thermal heat losses on thermal power output, output temperature and thermal efficiency. After conducting the experiments with combination of the various parameters significant parameters can be determined.

The next concept of this research is integrating the compound parabolic concentrators (CPC) with scheffler dish and testing the thermal performance of the integrated system for high temperature applications. Description of the integrated system can be given by using the mathematical concepts of thermal and heat transfer. Development of the mathematical model plays vital role to determine the energy production base on solar radiation and ambient temperature by considering heat losses. Mathematical model development for performance evaluation of the integrated system and validation by experimentation is very useful for various applications where the demand of high temperature solar thermal collector is more.

6. Expected outcomes

Integrated system can be effectively used for agricultural processing equipment and process industries.

Patent for new product development.

Useful solar based equipments for agriculture.

7. References

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Dnyaneshwar S Malwad
(Research scholar)

Dr. V. B. Tungikar
(Guide)
Professor, Production Engineering,
SGGSIE&T, Nanded